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I, JANENE PEISKER, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003907100 for a patent by KEVIN STEPHEN DAVIES as filed on 23 December 2003.

WITNESS my hand this
Twenty-fourth day of December 2004

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TEAM LEADER EXAMINATION
SUPPORT AND SALES

Simple Title

A control device 2.

Detailed Title

Machine control device using optics with infinite focal length and very long depth of field.

Initial scope of this provisional patent

This provisional patent covers an invention that may be used in other situations and for uses other than press brake control however its initial design and marketing is for press brakes where productivity and/or safety are improved by safely and automatically driving the blade to a position ready for bending material placed onto the anvil.

Overview

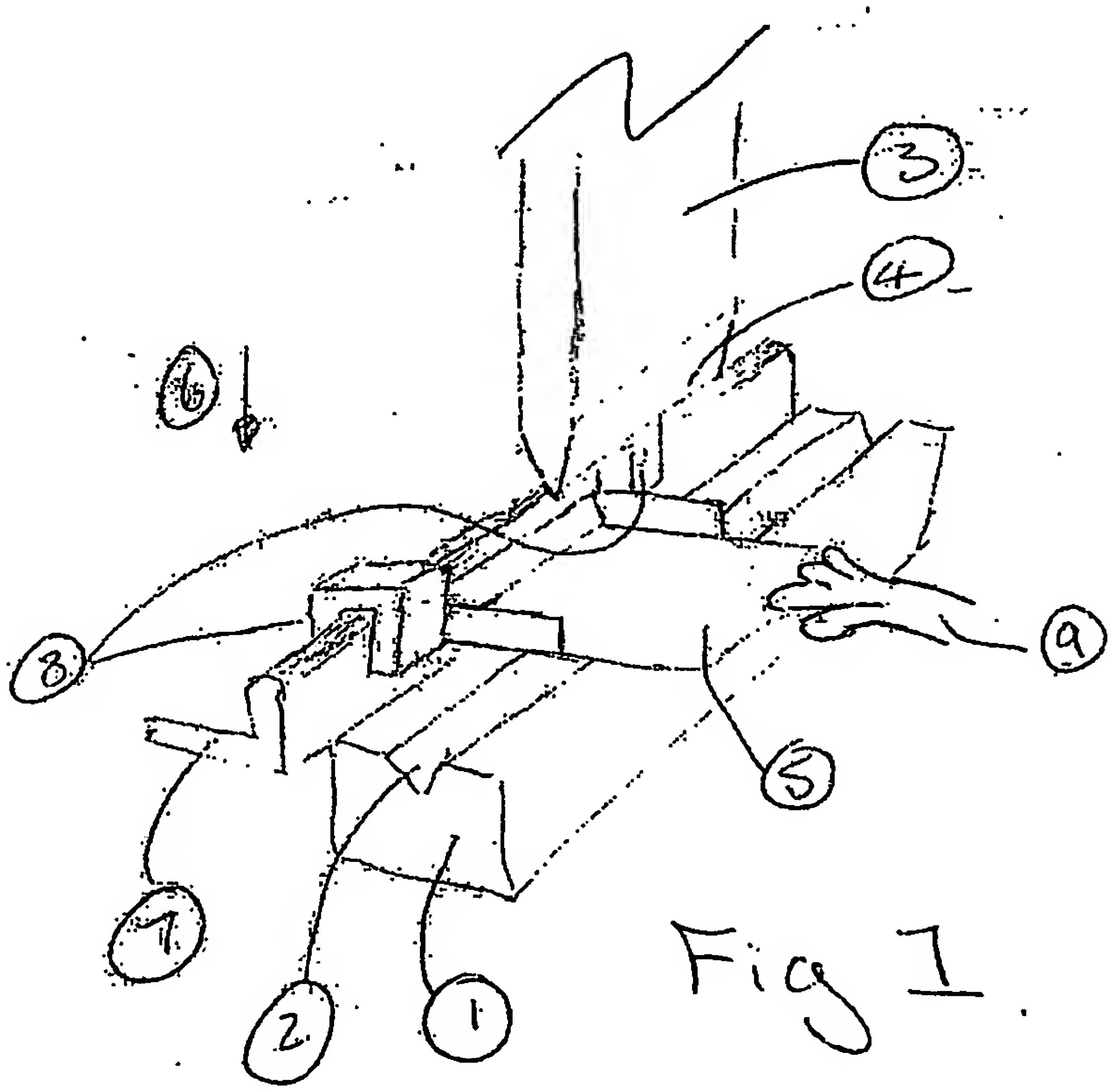


Fig 1

A typical break press has a long anvil (fig 1/1) with a VEE (fig 1/2) along the top and a blade (fig 1/3) with a leading bottom edge (fig 1/4) that fits into the VEE of the anvil. To bend a piece of sheet metal (fig 1/5), most machines drive a back-gage (fig 1/7) into a position to align the material, the material is slotted into the guide provided by the back-gage clamps (fig 1/8). The operator then activates the break press, driving the blade down (fig 1/6) so it comes into contact with, and then bends the sheet metal that has been placed onto the VEE of the anvil.

After the bend and if the blade has not been set to retract far enough then the material can be difficult to remove from the anvil.

For this reason, a press brake blade is often configured to retract to a height where the bent material can easily be removed, and a new piece placed onto the anvil to be bent.

This opening of the blade to a set height reduces productivity as the operator must wait for the blade to first retract and then approach the next piece of material that is placed onto the anvil in response to the operator activating an approach switch.

The large opening increases danger to the operator as there is a larger gap for the operator to put fingers & hands into. Techniques such as having a programmable blade opening height for each stage of the bending process and/or a very fast approach speeds to the material (with lasers projected along the underside of the blade for safety) have been used to improve productivity.

To improve safety, the blade may be stopped a preset distance (often called the mute – or pinch point) above the material and the approach switch required to be released and re-asserted again before the bending action starts. This action reduces productivity as extra time is spent:

1) While the operator aligns the material and then activates the approach switch.
2) While the blade approaches the material.
3) While the operator waits for the blade to stop at the mute point and to release and reassert the approach switch.

Laser beams projected along the underside of a blade can be used to ensure fingers are not placed on top of material and improve productivity by permitting the blade to travel straight through the mute point in relative safety. This method still leaves the operator at risk of entrapment (tips of fingers trapped between the bending metal and the blade) while a method to reduce the possibility of entrapment is described in PCT/AU03/00707.

When bending a box, an operator may bend the two sides of the box then rotate the work piece 90 deg to bend the back of the box. The operator then aligns the guide provided by the back-gage so the blade passes between the two sides. If the material isn't aligned correctly then the left or right edge of the blade can be broken, or the material crumpled due to the blade coming into contact with one of the up-stands. This would be likely to occur if the material is not seated properly into the back-gage guides when the approach switch is activated.

The operator may also use a laser system to make the blade stop just above the up-stands or configure such a stop into the machine, thereby permitting the operator to ensure the material is positioned correctly for the blade to pass between the sides without coming into contact with them. Due to the potential damage that can occur, operators often take extra care while performing these bends with productivity being reduced accordingly.

In another attempt to improve productivity, many presses are fitted with an auto-retract function. This is often achieved by waiting until the blade reaches its bottom of stroke and then automatically retracting the blade while the operator still has the approach switch activated.

An operator may also inadvertently place the material to be bent onto the bed oriented the wrong way leading to the wrong side of the material being bent.

Some or all of these techniques are limited in some way as they do not entirely solve the problem of productivity being reduced through either the blade opening being unnecessarily large or the blade being stopped at top dead center or other places waiting for the operator to re-activate the approach switch. Some or all of these techniques may also result in unnecessary time being spent configuring

the machine and/or unnecessary danger to the operator or potential damage to the machine or material.

The present invention seeks to at least in part to solve some or all of the problems described above.

The Invention

The contents of patent PCT/AU03/00707 are incorporated here by reference

The preferred embodiment for the new invention consists of the following:

Obstruction (blade/material and anvil) Sensing means:

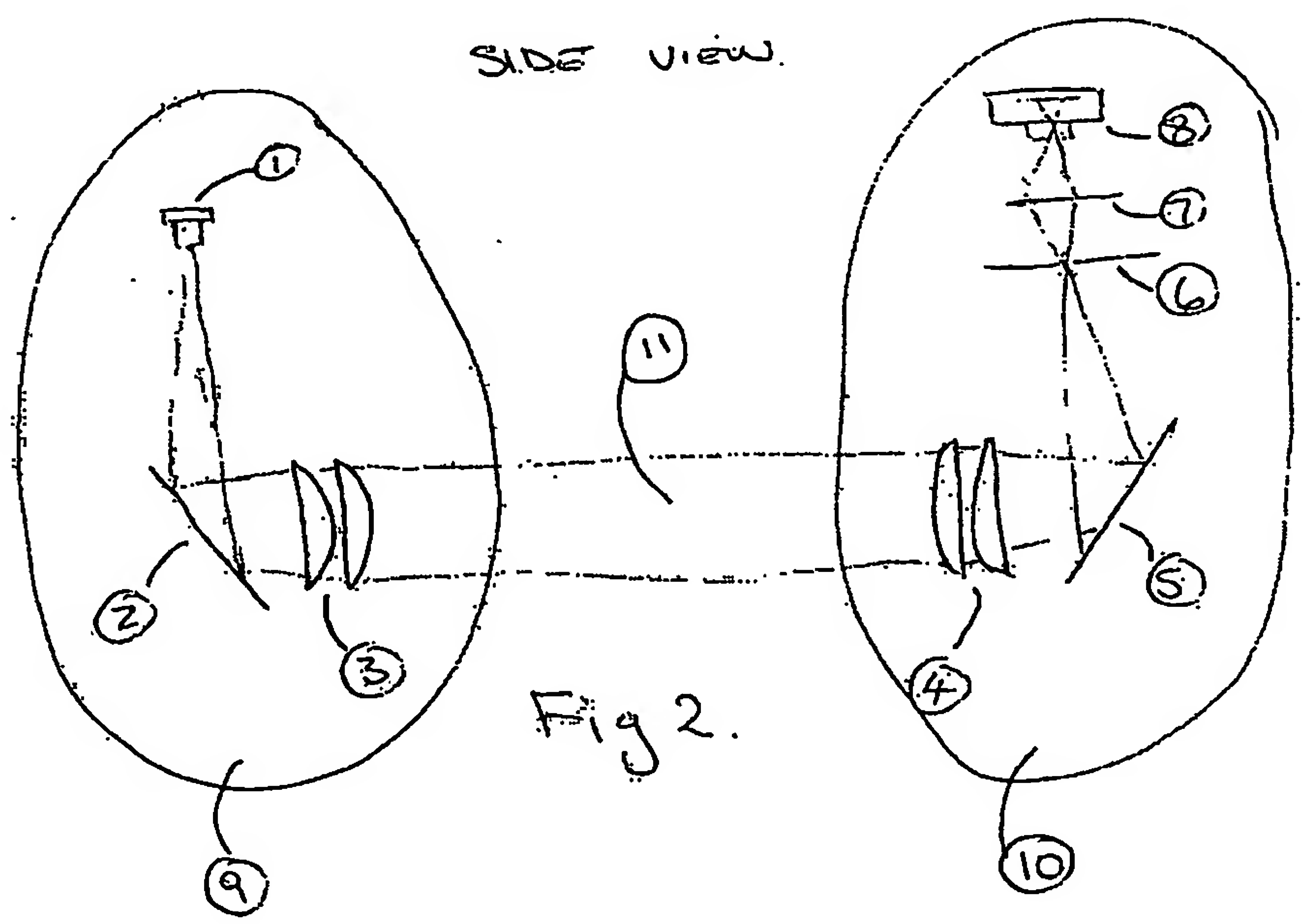


Fig 2.

A large area parallel ray light emitting means (fig 2/9) is used to illuminate the control zone (fig 2/11) so that objects illuminated by the light emitting means cast a shadow. The position, speed and shape of shadows are detected by a light receiving means (fig 2/10). A control means (not shown) analyses the information from the light receiving means and controls the machine accordingly.

The light emitting means (fig 2/9) consists of a laser diode (fig 2/1) that projects its diverging laser beam onto a mirror (fig 2/2). This mirror allows a long focal length to be used without making the device overly long.
Light from the mirror is columnated by the lens arrangement (fig 2/3) that may consist of aspheric, dual plano (flat on the back) convex lenses or other suitable converging lenses. The columnated light consists of substantially parallel rays of light projected over a large area.

The light receiving means (fig 2/10) consists of a lens arrangement (fig 2/4) to converge the large area light beam and also of a mirror (fig 2/5). The converged light is passed through a pin hole (fig 2/6) and onto a projection screen (fig 2/7).
The light hitting the projection screen creates and image that is detected in real time by a CCD camera (fig 2/8) and communicated to a control means (not shown).

Unlike the safety device described in patent PCT/AU03/00707, it may be necessary to keep the laser more precisely aligned with the receiver in order to accurately analyse the obstructions in the control zone (fig 2/11).

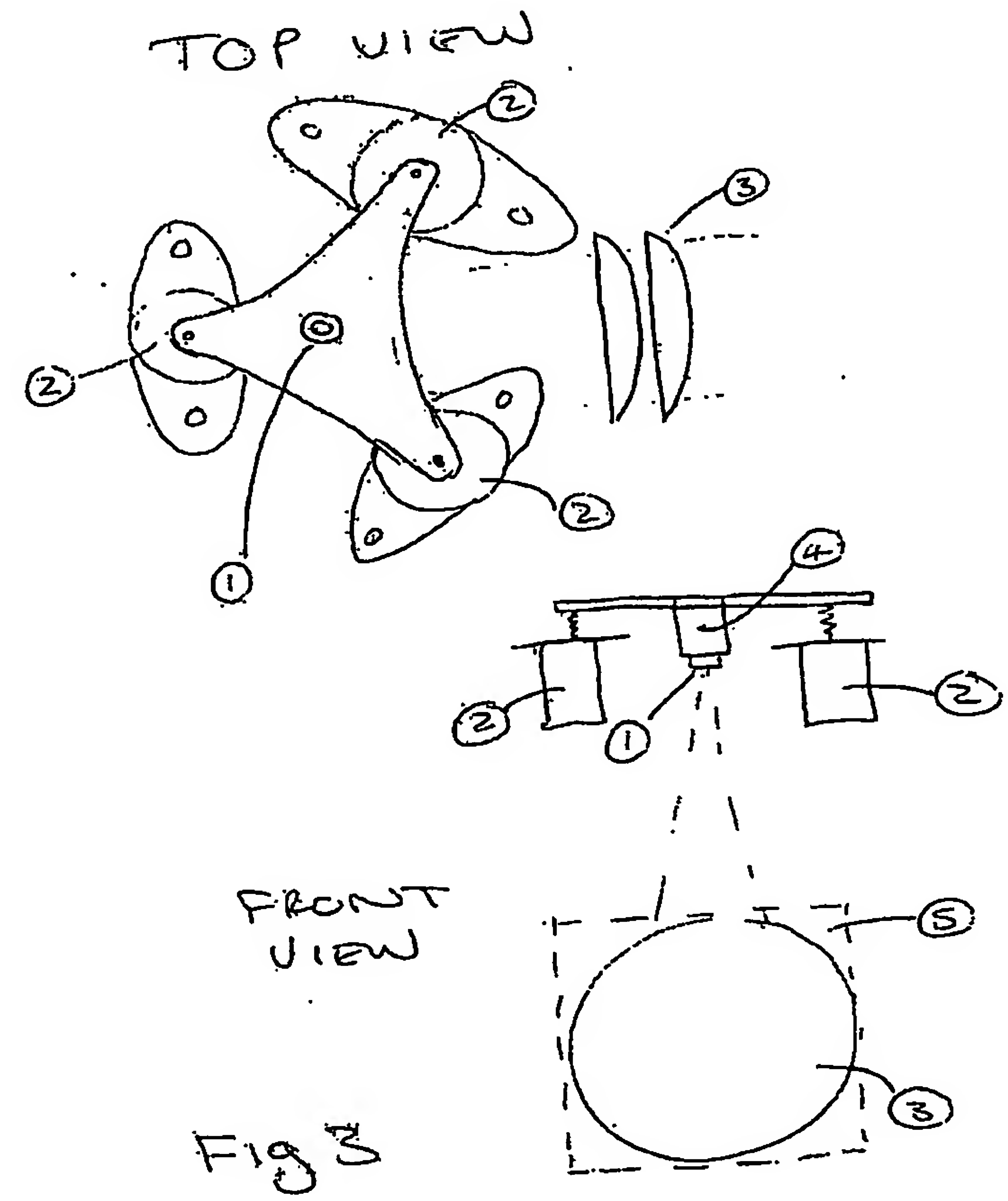


Fig 3

The preferred embodiment for aligning the laser beam has a vernier adjustment to automatically alter the direction of the columnated laser beam. This is achieved by moving the laser diode (fig 3/1) relative to the lens arrangement (fig 3/3) using three linear actuators (fig 3/2).

Moving the laser diode (fig 3/1) towards or away from the mirror (fig 3/5) so the optical distance to the lens arrangement (fig 3/3) decreases or increases causes the columnated laser beam to diverge or converge accordingly. The laser is moved laterally by mounting the laser below the fulcrum as shown in (fig 3/4). Moving the laser diode laterally relative to the lens arrangement alters the direction of the columnated beam without appreciably altering the quality of the columnated beam.

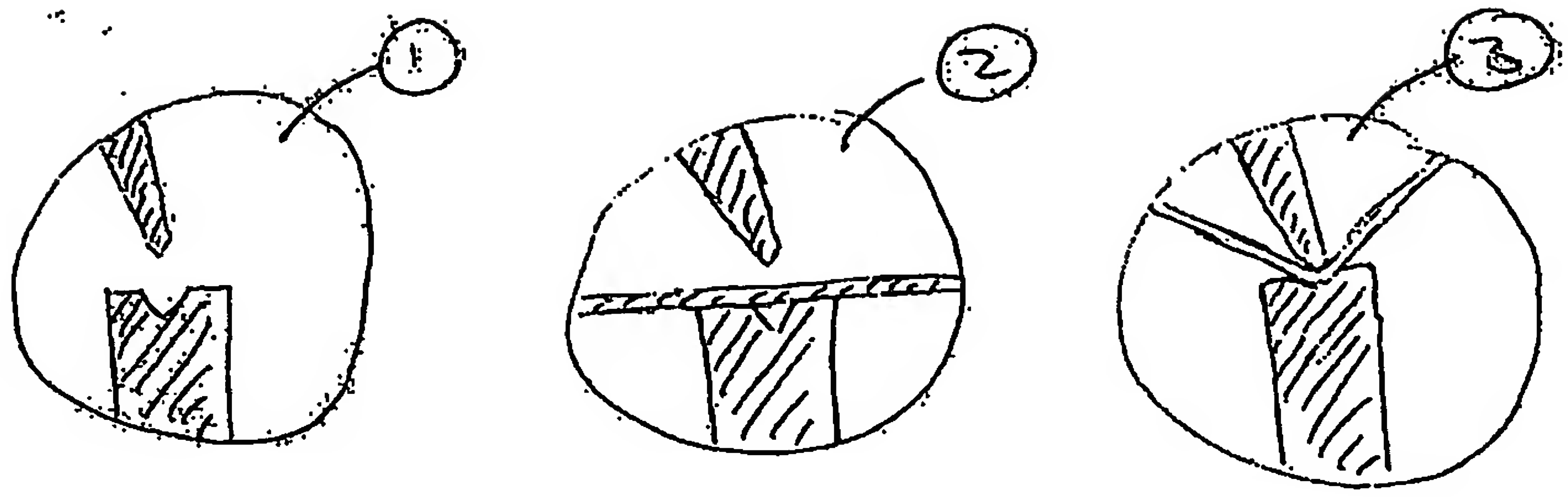


Fig 4

Fig 4 shows various images that could be analysed by the control means, these images may be:

- a blade and anvil with no material on the anvil (fig 4/1)
- a blade and anvil with material on the anvil (fig 4/2)
- a piece of material bent by the blade and anvil (fig 4/3)

Alternative embodiments for the obstruction sensing means could include multiple flat beam lasers (fig 5/2) as describe in WO03/080268 or multiple spot lasers (fig 5/1) positioned to achieve a similar outcome.

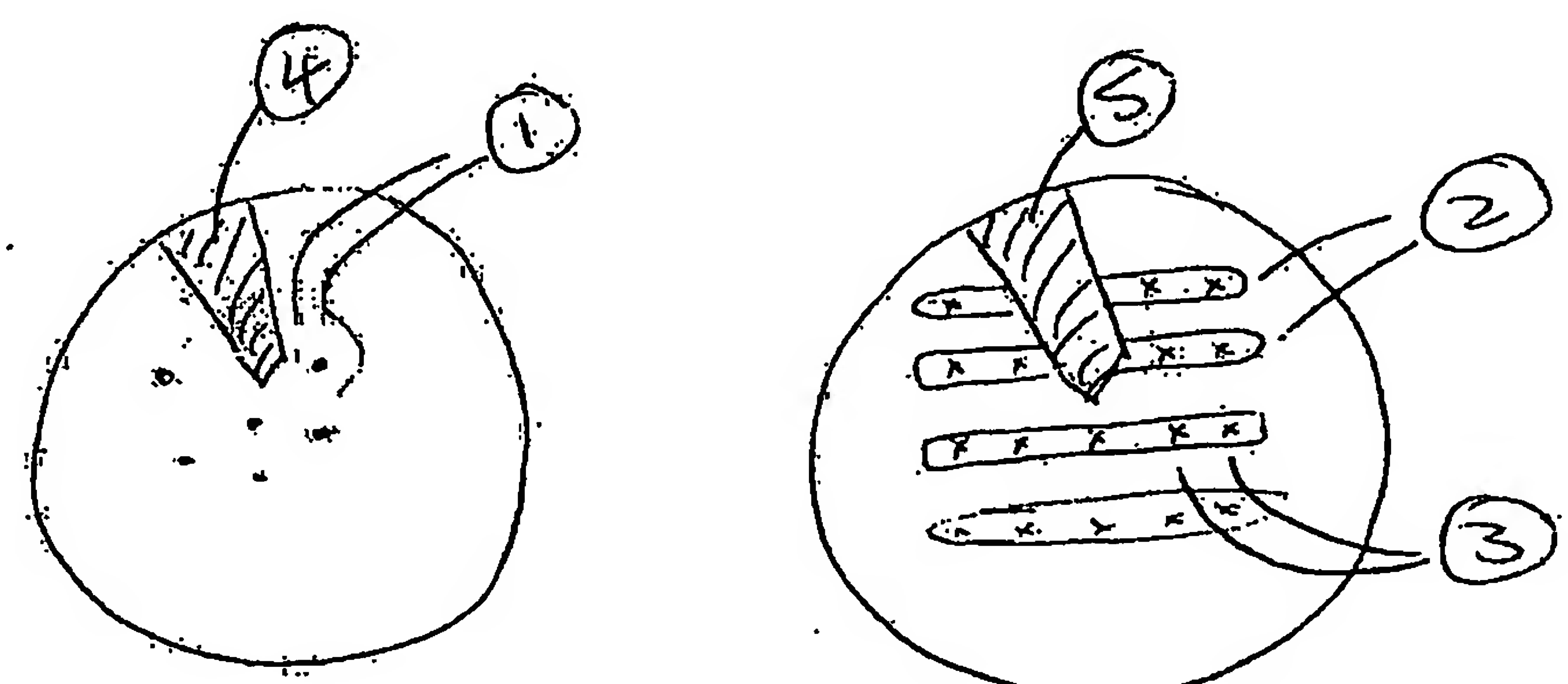


Fig 5

If many horizontal sensors (fig 5/3) are used (5 are shown here) then they can be used to determine the height that any obstructions occur at. To do this the blade position should be know at any moment and this information used to determine the height that a sensor is at when it becomes obstructed.

Material position sensing means:

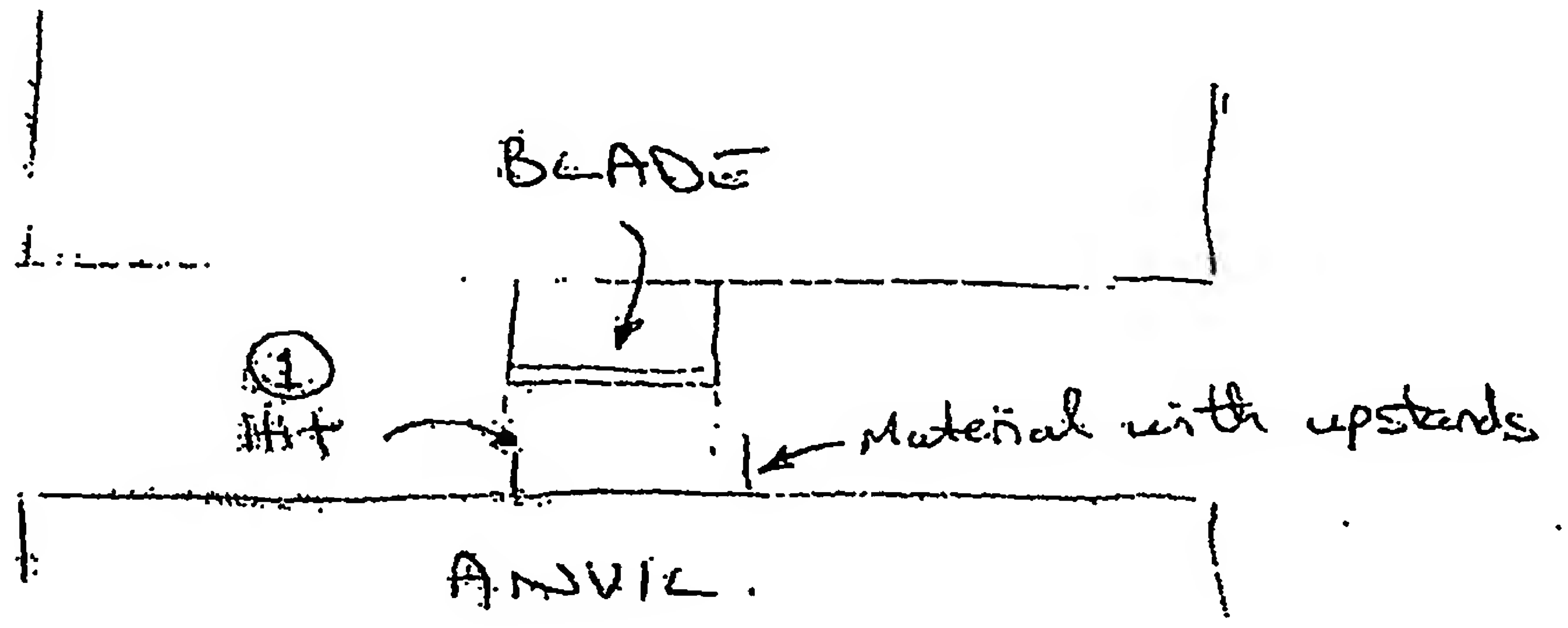


Fig 6

The image sensing means permits the control means to establish when a new piece of material has been placed onto the anvil and aligned front-to-back correctly, and also for the operator to work in safety as per PCT/AU03/00707. However, it does not permit the control means to establish if the material has been placed correctly laterally. Fig 6/1 shows a piece of material aligned incorrectly so that its up-stand will be hit by the blade. Material is not usually hit by a blade as a good operator takes the necessary precautions to ensure it doesn't happen.

The preferred embodiment for this invention includes a positive positioning or sensing means that can help ensure the material is horizontally positioned correctly.

The preferred positive positioning means requires the back-gage to have adjustable clamps as represented in Fig 1/8. As can be seen, the material can only be aligned when slotted between the two clamps of the back-gage.

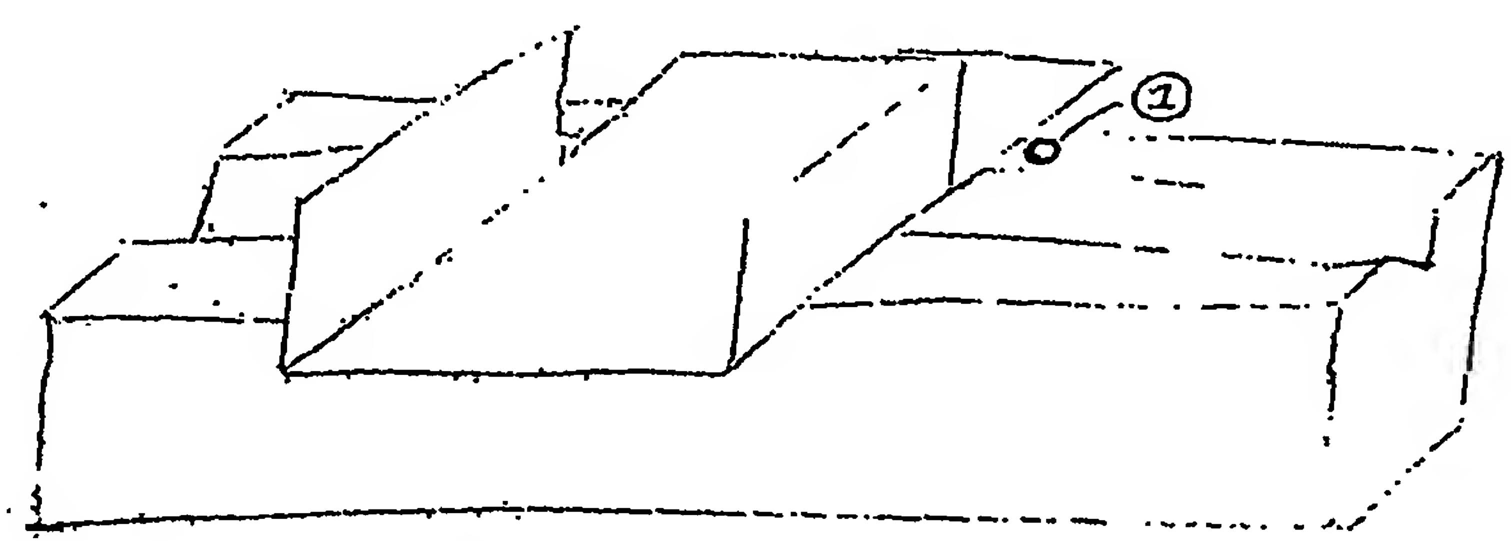
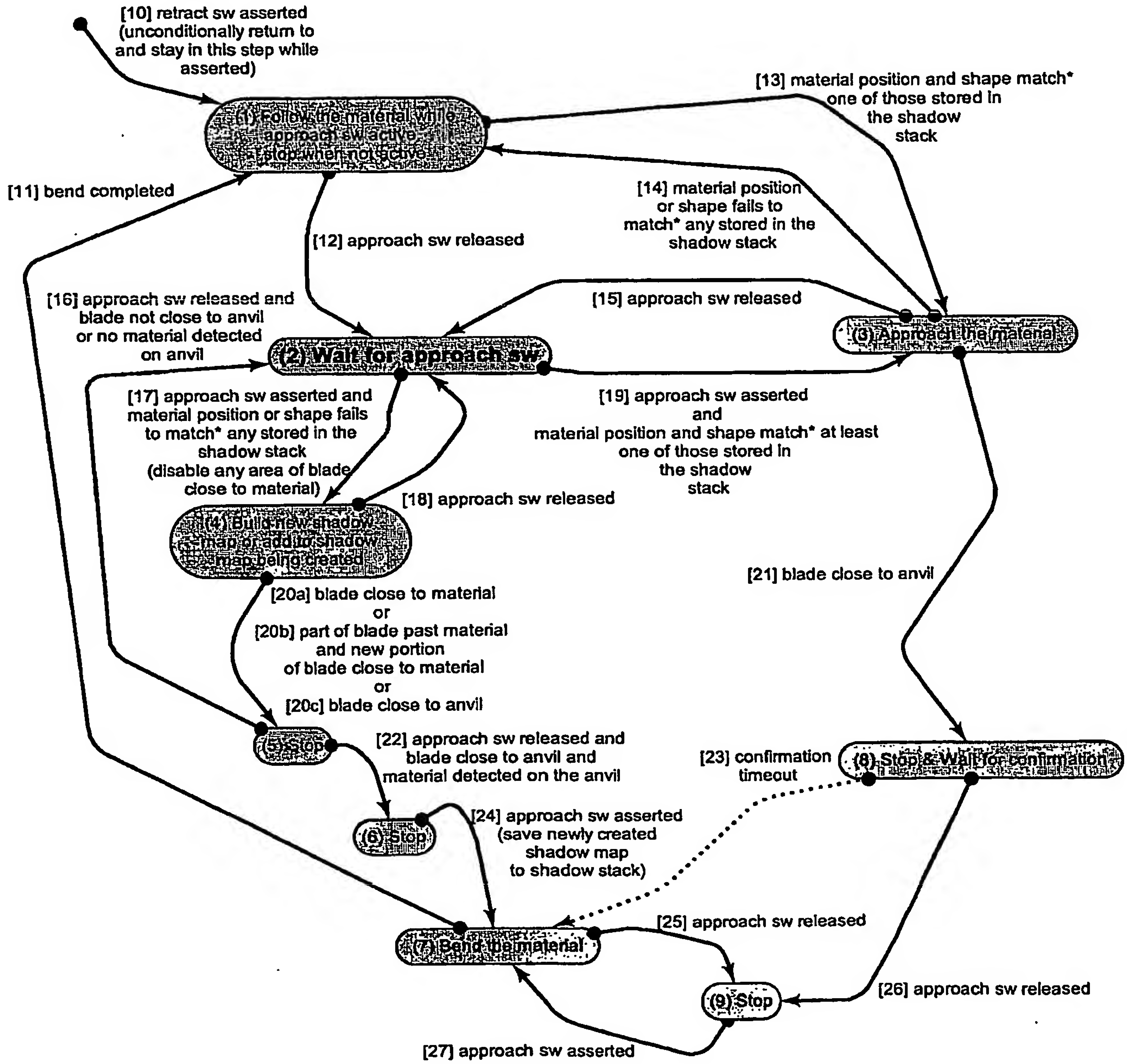


Fig 7

Fig 7/1 shows an inductive sensor mounted into an anvil with the material a little to the left, this would result in a low inductance from the inductive sensor. As the material position is varied from left to right, more of the sensor is covered. This results in the inductance to increase and/or the eddy current losses to increase accordingly.

The preferred material position sensing means has one or more inductive sensors mounted adjacent to, or into the anvil. By measuring the inductance of these sensors, the control means determines the relative horizontal position that the material has been placed into. Alternatively the inductive sensor or micro-switches could be mounted onto the alignment fingers of the back-gage to indicate to the control means that the material is positioned ready for the bend.



* If a material position sensing means is used then the inductance of the sensor is measured and stored with images when they are stored into the shadow stack When images are compared with the shadow stack, the inductance of the sensor is also compared against the stored value

Flow Diagram 1

Control means:

The control means (not shown) consists of a programmable device (say a DSP / microprocessor or computer) that analyses images from the light receiving means and controls the machine accordingly.

The control means includes the shadow maps and shadow mask expansion techniques that are described above (in PCT/AU03/00707) and also retains some or all of the safety techniques described in that PCT.

For the preferred embodiment, the control means also has a blade position sensor that permits the control means to know the position of the blade relative to the anvil. Alternatively, the control means can estimate the position of the blade relative to the anvil by observing the movement of obstructions (images of material and anvil) relative to the blade.

An overview of the control means operation is shown in flow diagram 1. States are numbered in the curved brackets, and conditions required to progress from state to state, shown in the square brackets.

To describe the operation of the control means, the bending of a simple box is described here.

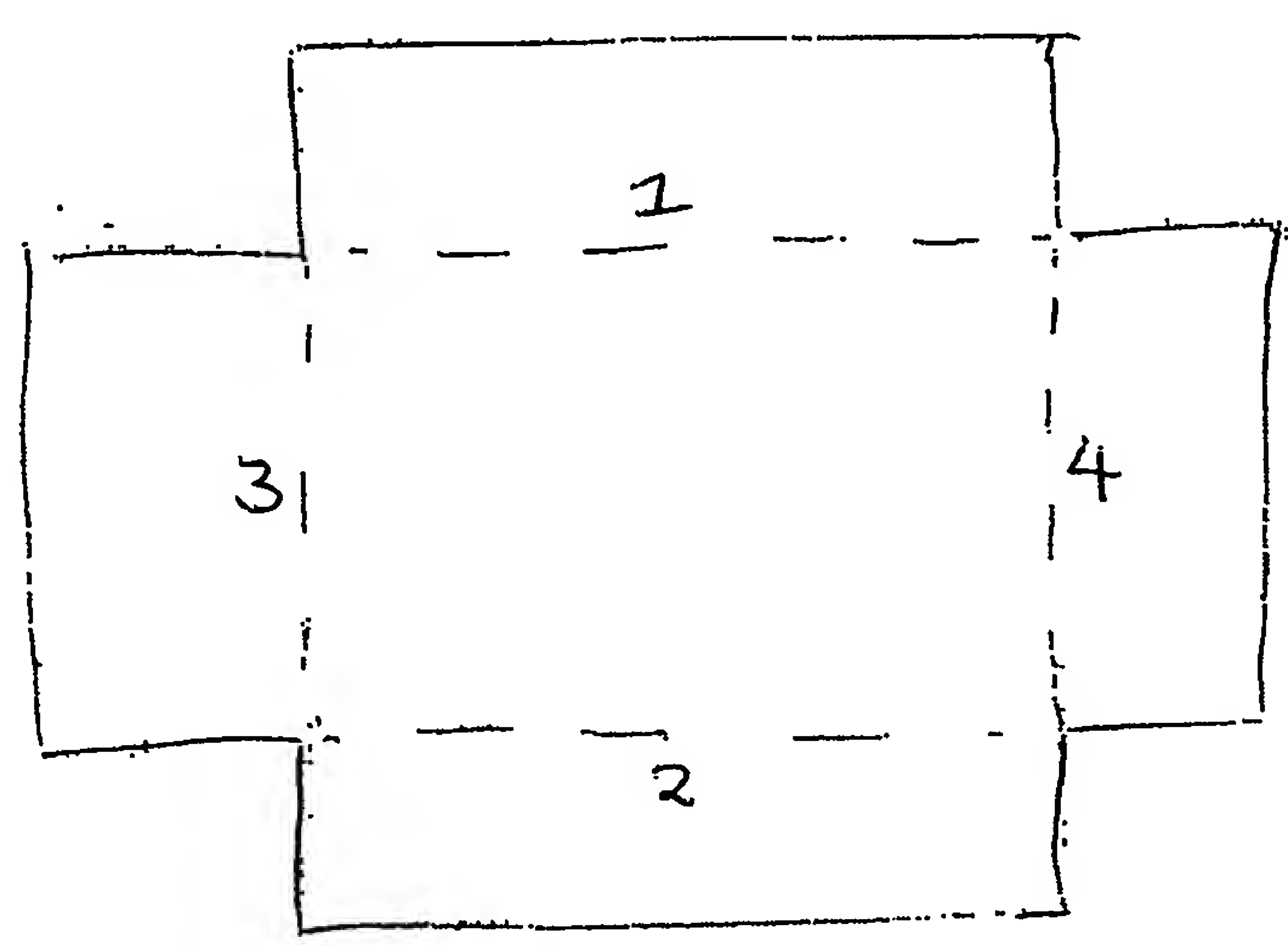


Fig 8

Referring to Fig 8, the shape of the material to be bent can be observed.

The operator activates the retract switch fulfilling condition [10] and forcing the control means to enter state (1).

The operator programs the required position of the back-gage for the first bend (fig 8/1) and releases the approach switch fulfilling condition [12] causing the control means to progress to state (2).

The material is placed onto the bed in the appropriate position for the first bend and the operator activates the approach switch fulfilling condition [17] so the control means enters state (4). In this mode, the control means drives the blade towards the bed until the blade becomes close to either the material or the anvil.

As a flat piece of material has been placed onto the bed, condition [20c] is met when the blade becomes close to the anvil *(the distance to the material is ignored if the blade is close to the anvil)*, and so the control means progresses to state (5).

In state (5) the blade is stopped and the operator releases the approach switch, fulfilling condition [22] as the blade is close to the anvil and material has been detected on the anvil. The control means is now in state (6). *If the operator were to activate the retract switch at this time then condition [10] would be met and the control means would jump to state (1) without saving the newly created shadow map into the shadow stack, however,* when the operator has checked the position of the material to be bent, the approach switch is re-activated, fulfilling condition [24] causing the control means saves the shadow map into the shadow stack and enters state (7).

In state (7), the material is bent and the bend completed, fulfilling condition [11] and returning the control means to state (1).

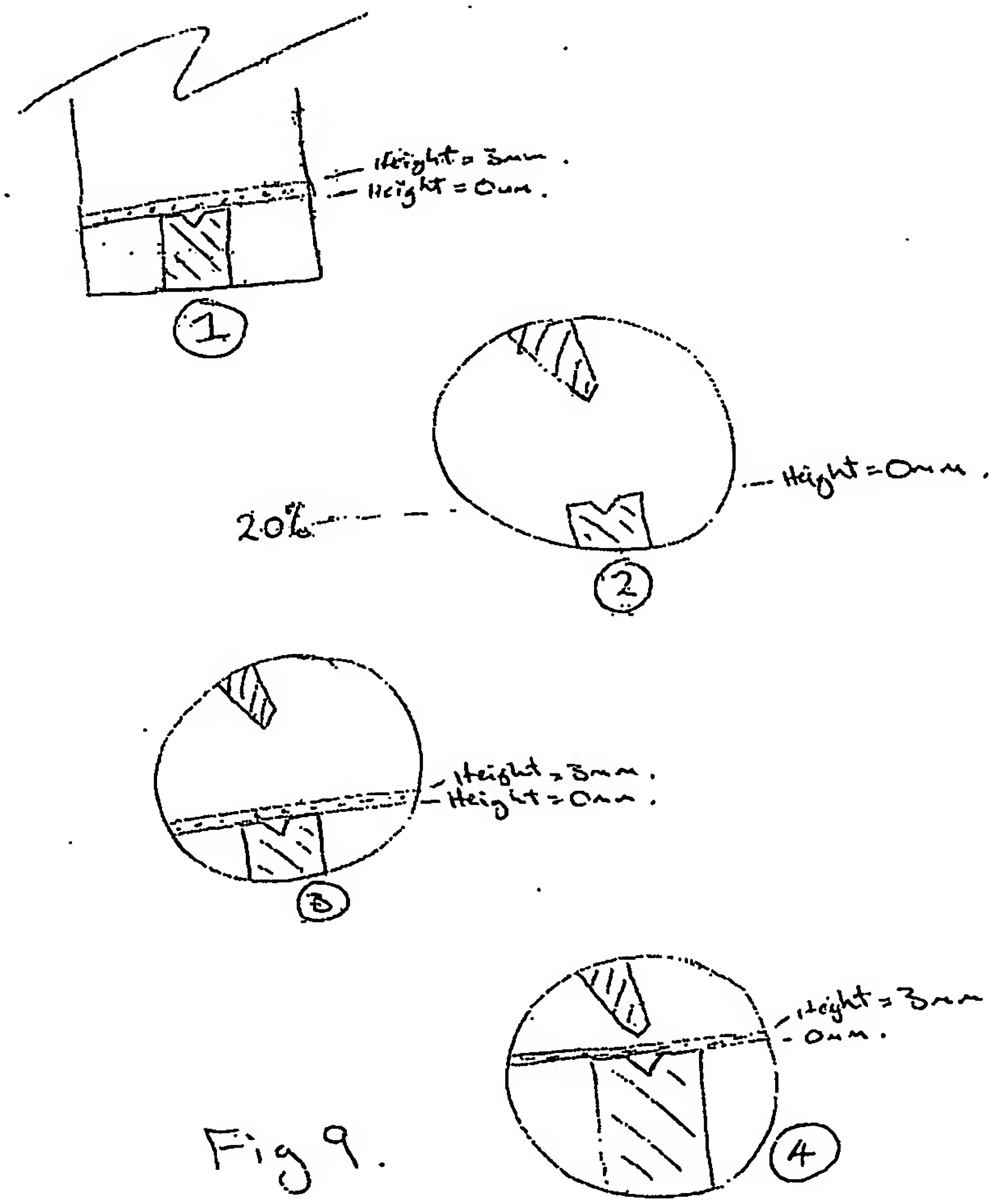


Fig 9.

In state (1), the control means retracts until the upper 80% of the visible area is clear (unobstructed), the lower 20% of the image is ignored except for checking for a match against images in the shadow stack. This causes the blade to retract so the operator is able to remove the bent material. When the material is removed, more than 80% of the visible area becomes clear. As the approach switch is still asserted, the blade approaches the anvil until the only the upper 80% of the visible area is clear. No material is on the anvil, and only one image exists in the shadow stack (fig 9/1). The image showing the anvil is different to the image in the shadow stack so the control means remains in state

(1) and keeps the blade at the position where only the lower 20% of the image is obstructed with an image (fig 9/2) that doesn't match the image in the shadow stack (fig 9/1).

The operator rotates the material through 180 deg and places it back onto the anvil to bend along the line (fig 8/2). When the material is flat on the bed, condition [13] is fulfilled and the control means proceeds to state (3).

In state (3) the image (fig 9/3) matches the image in the shadow stack, so the blade approaches the material until it is close to the anvil (fig 9/4). This fulfills condition [21] and the control means progresses to state (8).

In state (8) the blade is stopped until the approach switch is released and re-asserted putting the control means into state (7) and bending the material as before. Keeping in mind that safety is controlled by a different means, the operator could be permitted to configure the control device to drive straight through and not stop at state (8) or to insert a confirmation time as shown by the dotted line of condition [23].

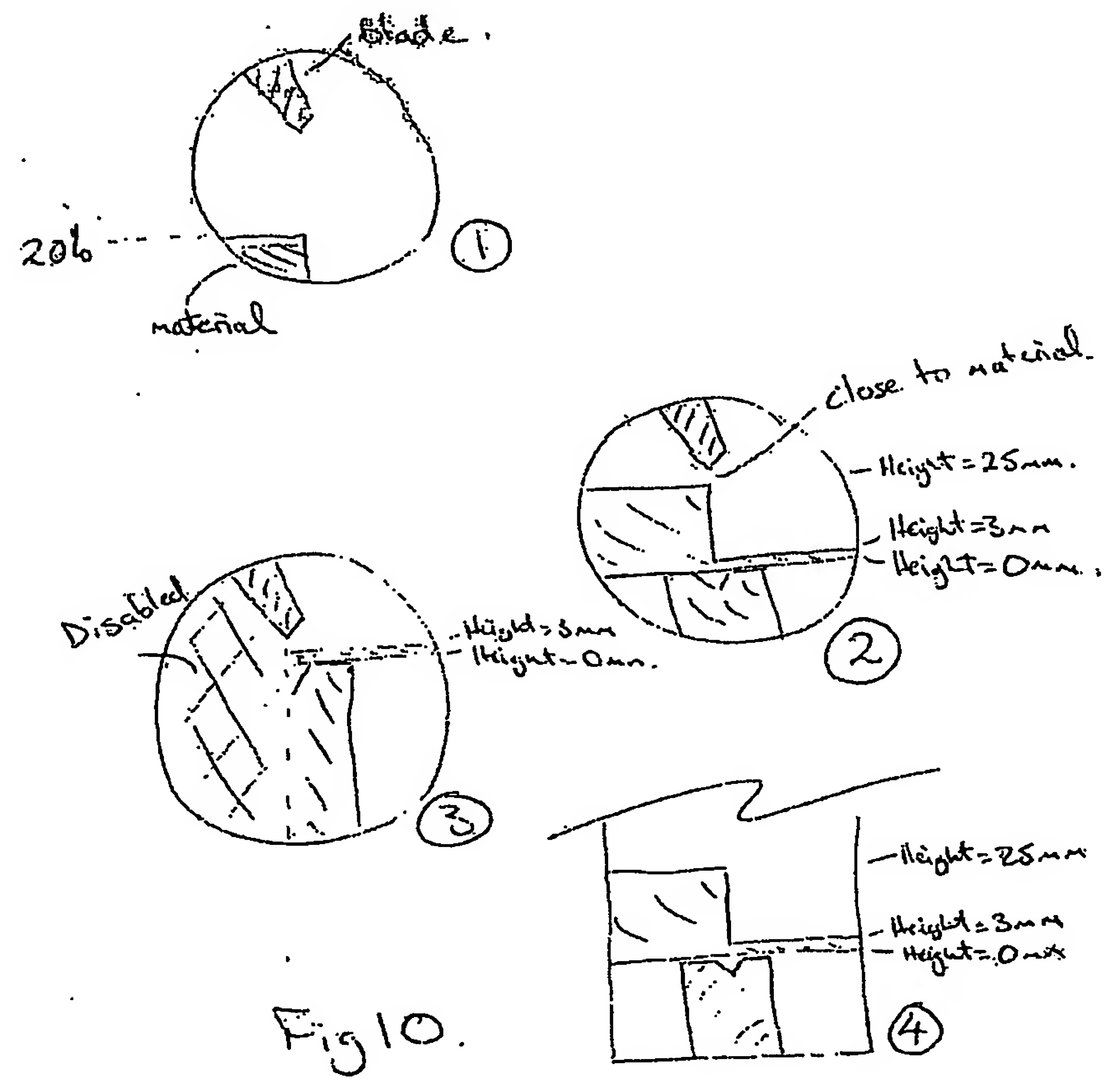


Fig 10.

The bend is completed and the blade retracts as described above. The operator rotates the material through a further 90 deg to bend along the line (fig 8/3). The control means would now be in state (1). The operator places the material onto the anvil so that the up-stand on the side of the box obstructs more than 20% of the image. This image is not in the shadow stack, so the blade is retracted until only the lower 20% of the image area (fig 10/1) is obstructed.

The blade remains in this position until the operator releases the approach switch putting the control means into state (2).

In state (2) the blade is stopped.

The operator asserts the approach switch fulfilling condition [17] and putting the control means into state (4).

In state (4) the blade approaches the anvil (and the material) until the blade is close to either the material or anvil. In this case, the blade becomes close to the material first due to the up-stands that have already been bent (fig 10/2). This satisfies condition [20a] and the control means enters state (5).

In state (5) the blade is stopped, the operator releases the approach switch. The blade is not close to the anvil so condition [16] is fulfilled and the control means returns to state (2).

The operator checks the alignment of the material and adjusts the back-gage clamps as necessary. The operator then activates the approach switch again fulfilling condition [17] and causing the control means to disable stops from further obstructions that would occur due to the upstanding material (fig 10/3). The control means is now back in state (4).

In state (4) the blade is driven towards the anvil with part of the image disabled (fig 10/3) so the control means can detect when a new portion of the blade becomes close to then material. The blade approaches the material until close to the anvil. This fulfills condition [20c] so the control means proceeds to state (5).

The bending process continues and the newly created shadow map (fig 10/4) is saved to the shadow stack as described above. After the bend is complete, the control means returns to state (1).

In state (1), the control means retracts until the upper 80% of the visible area is clear (unobstructed). This causes the blade to retract so the operator is able to remove the bent material. When the material is removed, more than 80% of the visible area becomes clear. The approach switch is still asserted so the blade approaches the anvil until the only the upper 80% of the visible area is clear. No material is on the anvil, and only two image exists in the shadow stack (fig 9/1 and fig 10/4). The image showing the anvil is different to either of the images in the shadow stack so the control means remains in state (1) and keeps the blade at the position where only the lower 20% of the image is obstructed with an image that doesn't match the image in the shadow stack.

The operator rotates the material through 180 deg and places it back onto the anvil to bend along the line (fig 8/4). When the material is flat on the bed, condition [13] is fulfilled and the control means proceeds to state (3).

In state (3) the image (fig 10/1 and then 10/2) matches one of the images in the shadow stack (fig 10/4), so the blade approaches the material until it is close to the anvil. This fulfills condition [21] and the control means progresses to state (8).

In state (8) the blade is stopped until the approach switch is released and re-asserted, putting the control means into state (7) and bending the material as before *(as described above, the blade could be permitted to drive straight through or insert a small delayed stop).*

To permit the best productivity, the blade speed would be fast where applicable.

Modifications and variations as would be apparent to a skilled addressee are deemed to be within the scope of the present invention.

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